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More than half of China's CO_2 emissions are from micro, small and medium-sized enterprises

Bo Meng[a,b], Yu Liu[c,d,*], Robbie Andrew[e], Meifang Zhou[f,*], Klaus Hubacek[g,h], Jinjun Xue[i,j], Glen Peters[e], Yuning Gao[k]

[a] Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO), Chiba 2618545, Japan
[b] Columbia Business School, New York, NY 10027, USA
[c] Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China
[d] School of Public Policy and Management, University of Chinese Academy of Sciences, Beijing 100049, China
[e] Center for International Climate Research (CICERO), Oslo 0349, Norway
[f] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China
[g] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA
[h] Department of Environmental Studies, Masaryk University, Brno 60200, Czech Republic
[i] Graduate School of Economics, Nagoya University, Nagoya 4648601, Japan
[j] Hubei University of Economics, Wuhan 430205, China
[k] School of Public Policy and Management, Tsinghua University, Beijing 100084, China

HIGHLIGHTS

- Firm size and ownership information is crucial in analyzing China's carbon emissions.
- MSMEs produced 53%, induced 65% of China's CO_2 emissions along domestic supply chains.
- Private MSMEs in the non-metallic mineral sector should be the key for policy-making.
- Given the abundance of MSMEs, taxation is suitable for further emissions reduction.
- Reducing environmental externalities in China need more supply-chain based governance.

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ABSTRACT

To date, the burden of CO_2 emissions reductions has been largely confined to large enterprises in China. Using new data with firm ownership and size information included, we show that micro, small and medium-sized enterprises (MSMEs) produced 53% of China's CO_2 emissions in 2010. Detailed supply-chain analysis reveals that final demand for products made downstream by domestic-private MSMEs, along with exports made downstream by foreign-owned MSMEs, are the main drivers of China's CO_2 emissions. Most of these emissions occur upstream in the electricity and heat sector, which is mainly controlled by large, state-owned enterprises with the highest carbon intensity, and the non-metallic mineral sector, which consists of a very large number of domestic-private MSMEs with lower levels of enforcement of emissions regulations. Overall, MSMEs induced 65% of China's CO_2 emissions through their supply chains. Our conclusion is that understanding the role of firm size for China is important in developing emissions reduction policies: given the very high per-enterprise overhead of emissions trading systems, and the abundance of MSMEs, our results clearly favour taxation.

1. Introduction

In 2015, China submitted its Intended Nationally Determined Contribution (INDC), including targets to "…peak CO_2 emissions by 2030 at the latest, lower the carbon intensity of GDP by 60–65% below 2005 levels by 2030…" [1]. While all of these commitments were made by the central government, they must be implemented at the firm level following a top-down policy process. Given the immense size of China

* Corresponding authors at: Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China (Y. Liu).
E-mail addresses: bo_meng@ide.go.jp (B. Meng), liuyu@casipm.ac.cn (Y. Liu), robbie.andrew@cicero.oslo.no (R. Andrew), zhou@bit.edu.cn (M. Zhou), hubacek@umd.edu (K. Hubacek), setsu@soec.nagoya-u.ac.jp (J. Xue), glen.peters@cicero.oslo.no (G. Peters), gao_yuning@mail.tsinghua.edu.cn (Y. Gao).

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as well as various pressures from the requirement of sustainable development, it is unclear if policies should prioritise small or large enterprises, state-owned, foreign-owned, or domestic-private enterprises. This is a crucial issue since different types of firms may have very different production functions, even when they are allocated to the same economic industry, thus may give very different responses to the same environmental policy.

To date, the burden of emissions reductions in China has been distributed to the provincial and city level following a top-down administrative process, and implementation and enforcement is largely confined to key sectors and large enterprises [2]. For example, the "Notice of Issuance of the Thousand Enterprise Energy Saving Action Implementation Plan" published by the National Development and Reform Commission of China [3], was the most important arm for emission reduction policies, covering only about 1,000 large energy and emission intensive enterprises, most of them state-owned. The coverage of the implementation plan was expanded to 10,000 enterprises in 2011 [4], but still covered only large emitters, which represented a very small proportion of the 11.9 million officially registered enterprises in China in 2011 [5]. When using a policy that requires tailored application to individual firms, focussing on a relatively small number of enterprises significantly reduces the administrative burden (e.g. monitoring, reporting, and verification costs for emissions) compared with coverage of all enterprises. Such policies become prohibitively burdensome to scale up. As a result, most important environmental policy targets in China, such as the domestic emissions trading schemes, emissions monitoring and enforcement targets, and subsidies and financial supports for green investment, tend to cover large enterprises and is limited to key industries.

The current focus on large enterprises assumes that these large companies are the major contributors to emissions and therefore they have been considered a low-hanging fruit for emission reduction policies. However, the total number of enterprises with official registration records increased from 9.7 million at the end of 2008 to 19.3 million at the end of April 2015 [6,7], of which more than 99%[1] were micro, small and medium-sized enterprises (MSMEs). Meanwhile, MSMEs accounted for 65% of China's GDP, 50% of the country's taxation revenue, 68% of national exports, and provided more than 75% of total employment at the end of 2014 [9]. The importance of MSMEs in the Chinese economy has been emphasized in a substantial amount of literature both academic research and business practice, but very little scientific and systematic evidence has been provided to show how much of China's CO_2 emissions are generated and driven by MSMEs at sector level and by firm type. This may directly influence environmental policy-making in China in which the importance of MSMEs in carbon emissions reductions has received little attention (e.g. [10]).

There have been only few studies on the measurement of CO_2 emissions and carbon footprints for China that explicitly consider firm heterogeneity exploring firm ownership and trading pattern information. Dietzenbacher et al. [11] showed that estimates of China's carbon emissions as embodied in its exports are reduced by more than 60% when firms who conduct processing exports and normal exports are separated in the Chinese input–output (IO) table. A similar phenomenon has also been pointed out by Su et al. [12], namely, the estimate of CO_2 emissions embodied in China's exports drops by 32% when the extended IO model with information on processing exports is used. As an extension, Jiang et al. [13] found that China's CO_2 emissions responsibility for each Yuan of national income from foreign-invested enterprises' exports, is actually higher than that attributable to Chinese owned enterprises' exports when using a recently developed environmental IO framework with firm ownership and trade mode information reported. Most recently, Liu et al. [14] further showed that ignoring firm heterogeneity causes embodied CO_2 emissions in Chinese exports to be overestimated by 20% at the national level, with huge differences at the sector level. They also pointed out that this overestimation is because different types of firm that are allocated to the same sector of the conventional Chinese IO table vary greatly in terms of market share, production technology and carbon intensity.

On the other hand, there is only limited research emphasizing the importance of firm size in studying energy efficiency and carbon emissions for China,[2] but most of these are at the sector level. For example, Teng and Gu [22] recommended that since half of China's emissions and pollution come from small and medium sized enterprises (SMEs) with limited ability and resources, the government should provide special financial and capacity building support to SMEs. However, they did not provide relevant evidence to support this conclusion. Wang and William [23] found that a large number of SMEs operate nonferrous metals production facilities which rank low in energy efficiency and therefore are highly energy intensive per unit of output. Based on a survey, they found that encouraging recycling is considered one of the most important tools for policy makers to help SMEs increase energy efficiency. Kostka et al. [24] studied financial, informational and organizational barriers to energy efficiency investments for SMEs in China based on a survey of 480 SMEs in Zhejiang province. They found that informational barriers are the core bottleneck inhibiting energy efficiency improvements for China's SMEs, and suggest that the Chinese government could play a more active role in fostering the dissemination of energy efficiency related information for SMEs. Wei et al. [25] performed statistical tests and found that large power enterprises in Zhejiang are less efficient in 2004, but became more efficient in 2008 than small power enterprises in terms of energy utilization and CO_2 emission based on the 2004 and 2008 Census data of Zhejiang province. Peng et al. [26] analysed the energy efficiency and carbon dioxide reduction in the Chinese pulp and paper industry in which 88.7% are SMEs. They found that this industry has further capabilities for energy-saving and carbon dioxide emission reduction by improving energy efficiency, and emphasize that policies for altering enterprise size are the most practical options to improve the energy efficiency of the pulp and paper industry at realistic levels. Cai et al. [27] evaluated the overall CO_2 emissions from cement industry based on the detailed information of China's total 1,574 cement enterprises in 2013. They found that SMEs contributed 38.1% of the total emissions in the cement industry; the total emission intensity for small, medium and large sized cement enterprises were respectively 0.896, 0.822, 0.814 t CO_2/t clinker. Their conclusion suggests that ownership of cement enterprises should be carefully considered in policies; favorable policies could focus on medium-sized facilities and facilities in foreign-invested enterprises. However, all the above studies rely on production-based energy and emissions accounting using survey data of a specific industry, rather than give a national view covering all industries and all types of firms in terms of their ownership and size. In addition, these studies could not provide more detailed analyses about energy or carbon footprints from a consumption-based accounting perspective due to the lack of IO data with available firm heterogeneity information included.

In this paper, we use a novel database, an augmented Chinese IO table for the year 2010 [28], in which information about firm size and ownership are explicitly reported, to investigate which types of

[1] There is no relevant information about the number of large enterprises in SAIC's statistics, but the number of large manufacturing enterprises based on the China's National Statistics Bureau (NBS)'s definitions on "enterprises above designated size" was never more than 10,000 in the period of 1998–2015 [8].

[2] For other countries, concerning the study about energy efficiency with information of firm size, one can refer to Cagno and Trianni [15], Trianni et al. [16] for Italy, Meath et al. [17] for Australia, Thollander et al. [18] for Japan and Sweden, Paramonova and Thollander [19] for Sweden, Agan et al. [20], for Turkey, Henriques and Catarino [21] for Portugal.

enterprise are responsible for generating China's CO_2 emissions, and, further, to compare the roles of firms in driving emissions within China's supply chains[3] as producers of intermediate and final products for both domestic and export markets based on both production and consumption-based emissions accounting. To the best of our knowledge, this is the first time that China's CO_2 emissions and carbon footprints are systematically estimated at both national and industrial levels with explicit information concerning firm size and ownership. Our results as shown in the following sections can greatly help better understanding on the fundamental economic and environmental questions: who produces CO_2 emissions for whom? Who is the main driving force of CO_2 emissions in China's domestic supply chains? What kind of policy is more suitable for small firms in the process of achieving China's emissions reduction goal?

2. Methods

Input–output analysis (IOA) is an accounting procedure and modeling approach that employs national or regional IO tables. A country's IO table shows product flows and thus interdependencies among suppliers and consumers along the production chain [31,32]. Given its ability to provide a cradle-to-grave perspective by accounting for impacts of the supply chain, IOA has gained importance in the estimation of embodied emissions in trade [33–36]. Using an environmentally extended IO model, we can estimate the embodied CO_2 emissions in final products or exports at the national level as follows [31]:

$$CO_2 = \mathbf{c}\cdot(\mathbf{I}-\mathbf{A})^{-1}\cdot\mathbf{f} \tag{1}$$

where CO_2 is a scalar representing total CO_2 emissions embodied in final products or exports; $\mathbf{c}$ is a $1 \times n$ row vector of CO_2 emissions coefficients representing CO_2 emissions per unit of economic output by sector; $\mathbf{A}$ is the $n \times n$ input coefficient matrix showing the share of intermediate inputs in total output; $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is the Leontief inverse matrix indicating total output induced by one unit production of final products or exports through domestic supply chains; and $\mathbf{f}$ is an $n \times 1$ column vector representing final products or exports by sector. According to different perspectives on supply chains, sectoral emissions embodied in final products or exports can be traced from downstream to upstream following the backward industrial linkage:

$$\mathbf{CO_2} = \mathbf{c}\cdot(\mathbf{I}-\mathbf{A})^{-1}\cdot\mathrm{diag}(\mathbf{f}) \tag{2}$$

$\mathbf{CO_2}$ represents CO_2 emissions in all sectors embodied in a specific final or exported product. This measure examines how a specific final or exporting product is associated directly and indirectly with emissions in all sectors via upstream domestic supply chains.

If we replace emission coefficient $\mathbf{c}$ in Eq. (1) with the value-added rate $\mathbf{v}$ (a $1 \times n$ row vector representing the value-added per unit output by sector), the embodied value-added (or GDP) in final products or exports also can be estimated by the following equation:

$$GDP = \mathbf{v}\cdot(\mathbf{I}-\mathbf{A})^{-1}\cdot\mathbf{f} \tag{3}$$

Using Eqs. (1) and (3), an indicator (P) of the carbon intensity of emissions embodied in final products or exports can be defined as follows:

$$P = CO_2/GDP \tag{4}$$

This indicator captures a country's emissions per unit of value added. It is a proxy for the potential national environmental cost of producing domestic final products or exports. In the same manner, sectoral value-added embodied in exports is given by the following equation:

$$\mathbf{GDP} = \mathbf{v}\cdot(\mathbf{I}-\mathbf{A})^{-1}\cdot\mathrm{diag}(\mathbf{f}) \tag{5}$$

Following the definition of P in Eq. (4), the carbon intensity of sectoral emissions embodied in final products or exports can be defined as follows:

$$\mathbf{P} = \mathbf{CO_2}//\mathbf{GDP} = [\mathbf{c}\cdot(\mathbf{I}-\mathbf{A})^{-1}\cdot\mathrm{diag}(\mathbf{f})]//[\mathbf{v}\cdot(\mathbf{I}-\mathbf{A})^{-1}\cdot\mathrm{diag}(\mathbf{f})] \tag{6}$$

We define "//" as an element-wise vector division operator. It is evident that carbon intensity for embodied emissions in a specific final or exporting product depends on the emission input coefficients ($\mathbf{c}$) and value-added rates ($\mathbf{v}$) of all upstream sectors.

Our analysis utilizes the augmented 2010 Chinese national IO table (42 sectors, Appendix Table A1). The layout of this IO table is in Appendix Table A2. We took the following steps to estimate CO_2 emissions by sector and firm type based on this augmented Chinese IO table. We first followed convention to estimate China's CO_2 emissions from burning fossil fuel using the 2011 Chinese Energy Balance Sheet from Chinese Energy Statistics Yearbook and IPCC emission factors [37]. We combined this information with monetary energy input data for four energy related sectors: (1) coal mining, washing and processing sector, (2) oil and gas mining sector, (3) petroleum processing, coking, and nuclear fuel processing sector, and (4) gas production and supply sector from the conventional Chinese national IO table. From our augmented IO table, it is straightforward to determine energy use in monetary terms (RMB) by sector and firm type. At the same time, from energy balance sheet, we can estimate the emissions by energy type. Assuming all enterprises pay the same price for each type of energy—a necessary assumption absent detailed and reliable price data, it is easy to calculate emissions per RMB for a specific energy type. With this figure and the augmented IO table, both emissions and value-added, thus carbon intensity by sector and firm type can be estimated. In addition, CO_2 emissions from cement production process are also estimated in terms of cement sector's output size and firm type.

While our quantitative analysis is based on data for the year 2010, making use of the most up-to-date augmented Chinese IO table available with firm ownership and size information included, this analysis is nevertheless still applicable and significant for China's current and near-future emission-related policy making. There are four key reasons for this: (1) since 2010 growth in the Chinese economy has slowed down, but its fundamental economic structure has changed much less than during the period leading up to 2010 (Appendix Table A3); (2) the energy use structure at both national and sector levels was very stable between 2010 and 2014 (Appendix Table A4); (3) while there has been no significant change in the number of state-owned enterprises, no significant difference in the change of fixed assets, nor in employment across enterprises with different firm size at the national level after 2010 through 2014, there have in contrast been very clear increasing trends in the number of private-domestic enterprises (15% per annum increase) and small-sized enterprises (6% per annum) in the same period (Appendix Fig. A1); (4) in terms of both firm numbers and value of fixed assets, the dominance of state-owned enterprises in the electricity and heat sector and that of domestic-private enterprises in the non-metallic mineral products sector have increased even further (Appendix Fig. A2).

3. Results

3.1. Firm-level contributions to China's CO_2 emissions

We estimate that China's total CO_2 emissions in 2010 were 8,747 $MtCO_2$. Of this, 329 $MtCO_2$ (3.8%) were generated by households and 8,418 $MtCO_2$ (96.2%) by industry. Of these industrial emissions, large enterprises contributed 47.5%, while MSMEs contributed 52.5% (Fig. 1). While the average carbon intensity of large enterprises is more than twice that of MSMEs, the latter generate almost three-quarters of China's GDP. The MSMEs in our IO table cover all non-large enterprises,

[3] Supply-chain based analyses on carbon emissions help better understanding on "who products emissions for whom" as well as emission transfers among production networks which covers all stages upstream and downstream. For detailed analytical examples, one can refer to [29,30].

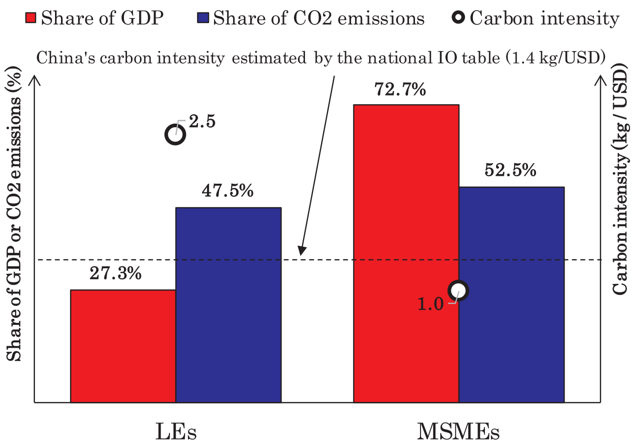


Fig. 1. China's GDP, CO_2 emissions, and carbon intensity by firm size in 2010. MSMEs are micro, small, and medium-sized enterprises, while LEs are large enterprises. The MSMEs have a larger share of GDP than CO_2 emissions, implying they have a lower average emission intensity. (For more information concerning detailed firm size and ownership, refer to Appendix Fig. A3).

including self-employed businesses (which are not registered as enterprises in SAIC). Therefore, the GDP contribution of MSMEs in 2010 (72.7%) measured here is larger than that in 2014 (65%) reported previously [9].

The differences of CO_2 emissions and carbon intensity across firm types at the national level depend on at least two factors. First, different types of enterprise may have very different representation in the various sectors of the economy according to economies of scale, market entry regulations or their market strategies in China. Second, even if they belong to the same economic sector, different types of enterprises may use very different technologies to produce their output. To explore these two issues in detail, we focus on the five largest sectors when ranked by emissions (accounting for 87.0% of China's total industrial emissions) and analyse their production-based CO_2 emissions, GDP and carbon intensities at the sector level for different types of enterprise (Table 1).

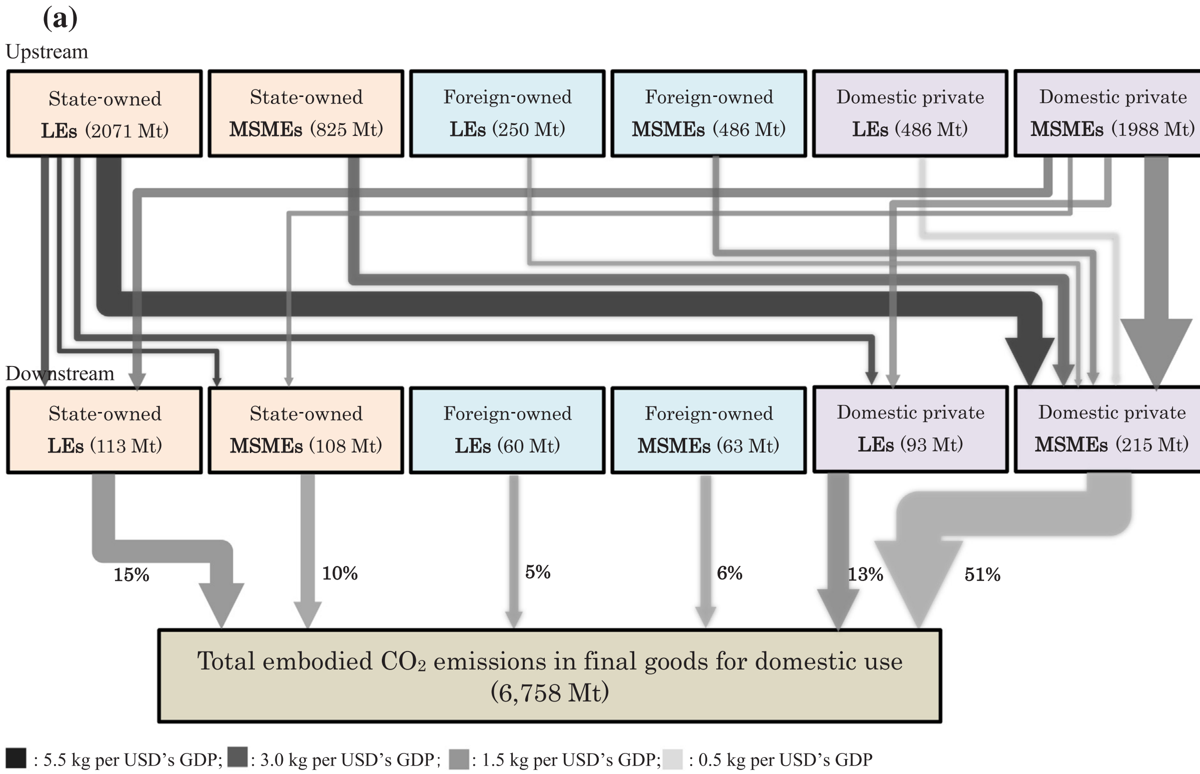
The electricity and heat sector generated 44% of China's CO_2 emissions and had the highest carbon intensity (22.8 $kgCO_2/USD$), but this intensity was considerably higher for large enterprises (29.6 $kgCO_2/USD$) than for MSMEs (15.6 $kgCO_2/USD$). One important reason behind this is that large enterprises use more coal than MSMEs to produce electricity. Coal-based energy input in monetary terms accounted for 88% and 73% of total energy inputs for large enterprises and MSMEs respectively in 2010. The non-metallic mineral products sector – producing cement, lime, glass, and ceramics – had the second-highest carbon intensity, at 11.6 $kgCO_2/USD$, and also made a relatively large contribution to national total emissions (18%). In contrast to the electricity and heat sector, more than 86% of both emissions and GDP in this sector were generated by MSMEs. A similar phenomenon is also found for the transportation and warehousing sector.

Clearly both LEs and MSMEs are important when considering emission reduction policies for the electricity and heat sector, because both have very high carbon intensity and therefore contribution to national emissions. More detailed information shows that about 83.3% of CO_2 emissions in China's electricity and heat sector were from state-owned enterprises in 2010 (Appendix Table A5). In contrast, the non-metallic mineral products sector is dominated by MSMEs. About 77.6% of CO_2 emissions in China's non-metallic mineral products sector was from domestic-private enterprises (Appendix Table A5). There are two

Table 1
CO_2 emissions, GDP and carbon intensity by firm size at the sector level. The five largest sectors ranked by emissions covered 87% of total Chinese CO_2 emissions and 18% of GDP, and exhibit large differences in firm-size distribution. The electricity and heat sector generated 44% of China's CO_2 emissions, but contributed only 3% to China's GDP. In this sector, large enterprises' carbon intensity was twice that of MSMEs. More than 80% of CO_2 emissions in the non-metallic mineral products sector and the transportation and warehousing sector were generated by MSMEs.

Sector	CO_2 emissions ($MtCO_2$)	Share by firm size	
		LEs	MSMEs
Electricity and heat	3699 (44%)	67%	33%
Non-metallic mineral products	1508 (18%)	14%	86%
Chemical	786 (9%)	38%	62%
Metal smelting products	760 (9%)	60%	40%
Transportation and warehousing	574 (7%)	18%	82%
All other sectors	1091 (13%)	42%	58%
National total	8418 (100%)	47%	53%
Sector	GDP (million USD)	Share by firm size	
		LEs	MSMEs
Electricity and heat	162 (3%)	52%	48%
Non-metallic mineral products	130 (2%)	13%	87%
Chemical	267 (4%)	31%	69%
Metal smelting products	216 (4%)	67%	33%
Transportation and warehousing	287 (5%)	25%	75%
All other sectors	4,901 (82%)	25%	75%
National total	5,963 (100%)	27%	73%
Sector	Carbon intensity ($kgCO_2/USD$)	Intensity by firm size	
		LEs	MSMEs
Electricity and heat	22.8	29.6	15.6
Non-metallic mineral products	11.6	12.4	11.5
Chemical	2.9	3.6	2.7
Metal smelting products	3.5	3.1	4.3
Transportation and warehousing	2.0	1.4	2.2
All other sectors	0.2	0.4	0.2
National average	1.4	2.5	1.0

key reasons for the large share of MSMEs in this sector. First, the sector is subject to a relatively small level of regulatory enforcement and also requires less sophisticated production technology, both of which have facilitated the entry of a large number of MSMEs, both foreign-owned and domestic. Second, the labour intensity of this sector is the second-highest in China (after textiles), so the sector is likely to be protected by local governments who prioritize job creation over environmental outcomes. Unlike the electricity and heat sector, the very large number of enterprises in the non-metallic mineral products sector means that the administrative burden of enforcing regulation and monitoring emissions of individual firms, as required by emissions trading schemes, would be very high. Based on the NBS statistics for the year of 2010, the electricity and heat sector covered 5,302 enterprises with 7,599 billion RMB fixed assets, in which 70% in terms of firm number, and 90% in



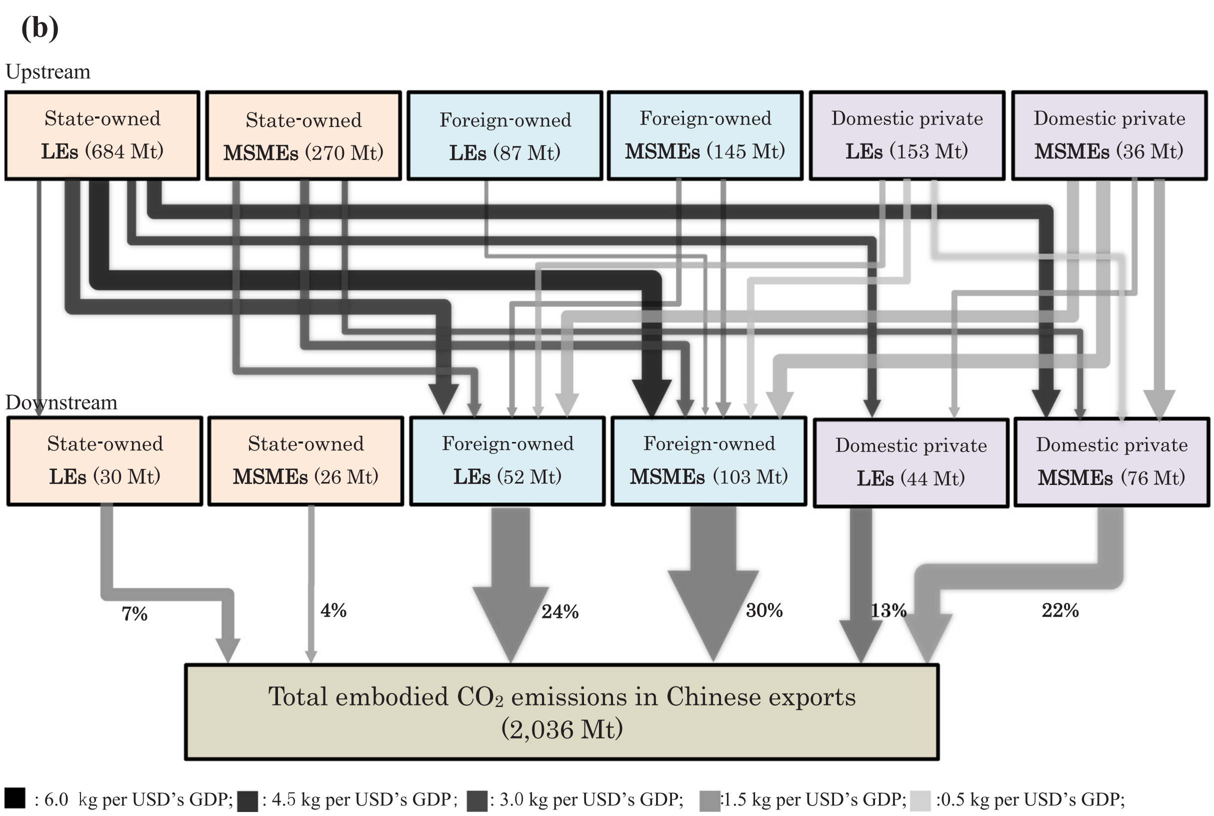


Fig. 2. Flow of CO_2 emissions induced by Chinese domestic final demand (a), and Chinese exports (b) along domestic supply chains. The arrow size represents the magnitude (in $MtCO_2$) of embodied CO_2 flows, while darker shades indicate higher carbon intensity ($kgCO_2$/USD). Domestic-private MSMEs downstream were the main driver in inducing emissions in Chinese domestic final demand, while the main sources of their emissions upstream were state-owned LEs and domestic-private MSMEs that provide intermediate inputs. The main drivers that induce CO_2 emissions in Chinese exports were foreign-owned enterprises downstream, but the greatest source of their emissions upstream were state-owned LEs.

terms of fixed assets were state-owned; the non-metallic mineral products sector covered 26,664 enterprises with 1,899 billion RMB fixed assets, in which 83% in terms of firm number, and 48% in terms of fixed assets were domestic-private. In this case, imposing carbon related taxation on enterprises in the non-metallic mineral products sector would be more suitable for emissions reduction.

3.2. Firm-specific drivers of China's CO_2 emissions

Rather than 'one size fits all' approaches, policymakers must understand firm-specific forces driving China's CO_2 emissions. This requires analyzing the supply chain with respect to production, consumption, and trade because emissions are driven through inter-firm and inter-industry linkages throughout the supply networks. From the production-based concept for emissions, there may be no need to separate goods by domestic final goods and exporting products since from the IO concept, there is just one uniform production function for a specific firm ignoring the differences when producing for domestic or foreign uses. However, when tracing emissions along supply chains from downstream to upstream, this separation is crucial to clearly understand who produces emissions (or value-added) for whom (domestic users or foreign users) via different kinds of supply chain routes, and how the structure of supply chains differs with regard to emission generation. From the supply chain perspective, we investigate CO_2 emissions in two distinct stages. Emissions in the first stage originate upstream in the production of intermediate inputs (e.g. parts and components destined for use in production of smartphones), while emissions in the second stage originate downstream in the production of domestic final products or exports (e.g. production of smartphones themselves). Domestic value-added arises during both stages and can be summarized using the same approach as used for emissions. This approach permits investigating carbon intensity of CO_2 emissions embodied in final products and exports along China's domestic supply chains as shown in Eq. (6). This new indicator can be used to measure the entire supply chain emissions concerning a specific final or exporting product when one unit of value-added is generated. In this sense, it can also be regarded as an indicator for potential environmental costs along supply chains [14,29,38].

Fig. 2(a) distinguishes the upstream (i.e. from resource extraction and imports to intermediate production) and downstream (from intermediate production to final production) elements of China's domestic supply chains. For detailed presentation of the supply-chain results, we separate enterprises located in China into six categories by ownership[4] (state-owned, foreign-owned, and domestic-private enterprises) and size[5] (large enterprises: LEs; micro, small and medium-sized enterprises: MSMEs). Downstream enterprises include only those that produce final goods and services or exports. Fig. 2(a) also includes upstream enterprises that provide intermediate products to downstream enterprises directly and indirectly.

Total embodied CO_2 emissions in products for domestic final demand were 6,758 $MtCO_2$ in 2010, of which 51% were induced by domestic-private MSMEs. Downstream domestic-private MSMEs directly generated fewer emissions (215 $MtCO_2$) than upstream domestic-private MSMEs (1,988 $MtCO_2$), the latter with higher carbon intensity. State-owned LEs upstream generated emissions of 2,071 $MtCO_2$ with higher carbon intensity. The other important firms downstream were state-owned LEs and domestic-private LEs, which induced 15% (1,024 $MtCO_2$) and 13% (879 $MtCO_2$), respectively, of emissions embodied in China's domestic final demand. The main sources of these carbon-intensive enterprises' emissions are upstream state-owned LEs and domestic-private MSMEs that provide their intermediate inputs. Flows of carbon emissions between downstream domestic-private MSMEs and upstream state-owned LEs, state-owned MSMEs, and domestic-private MSMEs, diminish in intensity during the progression toward final consumers. This demonstrates that downstream enterprises generate more value-added and fewer emissions than upstream enterprises in China's domestic supply chains.

We apply the same approach to evaluate firm-level CO_2 emissions embodied in Chinese exports. As Fig. 2(b) shows, downstream enterprises include only exporters. The total CO_2 emissions embodied in Chinese exports were 2,036 $MtCO_2$ in 2010, of which more than half were induced by foreign-owned enterprises (30% for foreign-owned MSMEs, 24% for foreign-owned LEs), but most emissions were generated by state-owned enterprises upstream. This is because high carbon-intensive intermediate inputs (particularly electricity) used by downstream enterprises producing exports come mainly from state-owned enterprises. Overall, when emissions embodied in domestic and foreign demand are combined, downstream MSMEs induced about two-thirds (65%[6]) of China's industrial CO_2 emissions in 2010.

4. Conclusion and discussion

Detailed sector-level analysis of production and associated supply chain emissions within an economy often overlooks the fact that different types of enterprises within an economic sector vary significantly in terms of market share, production technology, and carbon intensity. Using an augmented Chinese input-output table that reports firm ownership and size, we have identified firms and sectors that should be targeted to reduce China's carbon emissions. We show that micro, small and medium-sized enterprises (MSMEs) contributed 53% of China's CO_2 emissions in 2010, notably in the non-metallic mineral and transportation sectors. Although 68%[7] of MSMEs' products have relatively lower carbon intensity compared to those for LEs, their increasing numbers and contribution to the Chinese economy (73% of GDP) make them a main driver of China's CO_2 emissions. Further, while it is widely reported that the electricity and heat sector is the most important emitter, our analysis adds detail by showing that 83.3% of these emissions were generated by state-owned enterprises with very high emission intensity. Similarly, many studies emphasize the importance of the non-metallic mineral products sector in China's emissions reduction, but we show that about 77.6% of CO_2 emissions in this sector were from private-domestic enterprises with higher carbon intensity than foreign-owned enterprises.

Introducing firm heterogeneity into a supply-chain analysis deepens understanding of how China's domestic final demand and exports influence CO_2 emissions. In total, MSMEs induced 65% of China's emissions. Domestic-private MSMEs are the main driver, with 51% of national emissions induced by their production for fulfilling domestic final demand. Our analysis also shows that 54% of emissions embodied in exports were induced by foreign-owned enterprises in their supply chains, but the greatest sources of these emissions upstream are large state-owned electricity generators and MSMEs producing non-metallic mineral products. China's electricity and heat sector—the most important upstream supplier of production inputs—is dominated by state-owned enterprises protected by significant barriers to foreign and

[4] The ownership type of an enterprise in the paper is defined based on the registration type and equity share by ownership [28]. Specifically, a firm is considered state-owned (foreign-owned) if it is registered as a state (foreign) company or has 50% or more equity owned by state (foreign) investors.

[5] Firm size category (LEs and MSMEs) is determined by firm employment and sales, with thresholds specified by the NBS ([39]; for details see Appendix Table A6).

[6] From Fig. 2(a), (b), the share of MSMEs' contribution in total embodied emissions can be estimated as follows: $[(10\% + 6\% + 51\%) * 6758 + (4\% + 30\% + 22\%) * 2036]/(6{,}758 + 2{,}036) = 65\%$.

[7] From Table 1, the share of MSMEs' products with relatively lower intensity can be estimated as follows: $(162 * 48.2\% + 130 * 87.1\% + 267 * 69.0\% + 4901 * 74.9\%)/5{,}963 = 68\%$.

private investment as well as inefficient subsides. For example, state-owned large thermal power plants and heat utilities benefited greatly from urban land-use tax concessions, preferential loans, loan guarantees and other support provided by central or local governments. These entry barriers and subsides may distort market mechanisms and price signals, discourage competition, and lower international technology transfer in upstream sectors. These apply not only to the electricity sector; China's energy market has historically been characterized by highly regulated production and retail prices, and in most upstream energy resource sectors (e.g. coal, oil and gas sectors), vertically integrated state-owned enterprises play a central role in various stages of the supply chain [40].

In contrast to the electricity sector, lax regulatory enforcement, and low production standards in non-metallic mineral products attracted large numbers of private MSMEs to that sector. In the cement industry alone there are more than 3,500 enterprises [41], almost half of which are making a loss [42]. As a consequence, prices in this sector do not fully reflect the environmental cost of energy consumption, lower prices stimulate over production, and thus more emissions occur in the non-metallic mineral sector upstream in the supply chain.

It is clear that the competitiveness of "Made in China" exports in international markets and final products made by private MSMEs in domestic markets is partly due to environmental externalities mainly generated by upstream enterprises[8]. China has committed to move toward more market-based prices and toward taxes that internalize environmental damage caused by economic activities [40]. However, a much clearer timeline for market-oriented reform, especially of upstream state-owned enterprises with high information transparency and less price control, should be a priority for reducing emissions in China along the whole supply chain. Market-oriented reforms of state-owned enterprises upstream can help market prices play an essential role in resource allocation along the whole supply chain, and can also give a positive response to the controversial issue of the so-called "Market Economy" status for China in the context of the World Trade Organization (WTO) trading system, which is currently not granted by the US, the EU and Japan. On the other hand, for the very large number of private MSMEs in the non-metallic mineral sector, enhancing regulatory enforcement and introducing higher standards are essential for both reducing their emissions and enhancing industrial upgrading.

Given the diversity of MSMEs and their dominant contribution to emissions in non-metallic mineral products and transportation sectors, taxation should be the first tool for reducing emissions. In China's ongoing debate between instituting a carbon tax or emissions trading, and given the very high per-enterprise overhead of emissions trading systems, our results clearly favor taxation because of significant emissions both generated and induced by the abundance of MSMEs. The fact is that even the national integrated emission trading market across all industries, scheduled for 2018, just 7,000–8,000 enterprises whose energy use is more than 10,000 tce can be involved, according to the recent report by the Department of Climate Change, China National Development and Reform Commission[9]. While, imposing a carbon tax on MSMEs provides other challenges given the difficulty of having CO_2 emissions information for such a large number of MSMEs in China. One possible way is to use an energy tax as a proxy. This requires a survey based analysis that can provide supporting evidence to better match the effects of an energy tax with a carbon tax with limited losses of economic efficiency (for example, see [43]).

In addition, green finance has been considered one of the most important tools to help firms invest on low-carbon technology and thus improve their energy efficiency. However, the fact in China is that large firms, especially state-owned firms, are likely to receive preferential terms for financing investment in energy-efficient technologies and equipment, including no- or low-interest loans and easier access to public funds. On the other hand, most MSMEs have to rely on self-financing, including owners' capital and corporate revenue. Such self-financing often results in firms focusing on short-term profit and may make them reluctant to invest in research and development or engage in innovation activities, which tend to be long-term. Limited access to financial resources is listed as the second-most severe obstacle to innovation in SMEs in China [44]. This will also affect emission reduction efforts by MSMEs since investments in energy efficient technologies and equipment also take a long time to pay off. Therefore, elimination of the preferential subsidy for large and state-owned firms can help equalize the financial costs for green investment across firms and thus increase the economic efficiency of emission reduction for MSMEs.

In general, climate policy enforcement efforts so far in China have left the majority of smaller and private firms unaffected or less affected, thus impeding major future breakthroughs in greenhouse gas mitigation. At the same time, tighter mitigation targets are set for the coming decades in China. Since low-hanging fruit for emission reductions is becoming rarer, the economy has seen decreasing effectiveness of existing policy tools and increasing costs for further greenhouse gas mitigation. Given the findings of the paper, policymakers need to pay more attention to the emission reduction potential of MSMEs.

Our analysis of China is also a very important reference for other developing economies (e.g., India, Indonesia) who may face a similar situation at present or in the near future. Namely, a large number of domestic-private MSMEs are playing an increasingly dominant role in both economic activities and environmental impact, but this receives insufficient attention in policy making for CO_2 emissions reduction.

Acknowledgements

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[8] Liu et al. [14] and Meng et al. [30] provided similar evidence.
[9] http://cdm.ccchina.gov.cn/Detail.aspx?newsId=67067&TId=1

Appendix A

See Figs. A1–A3 and Tables A1–A6.

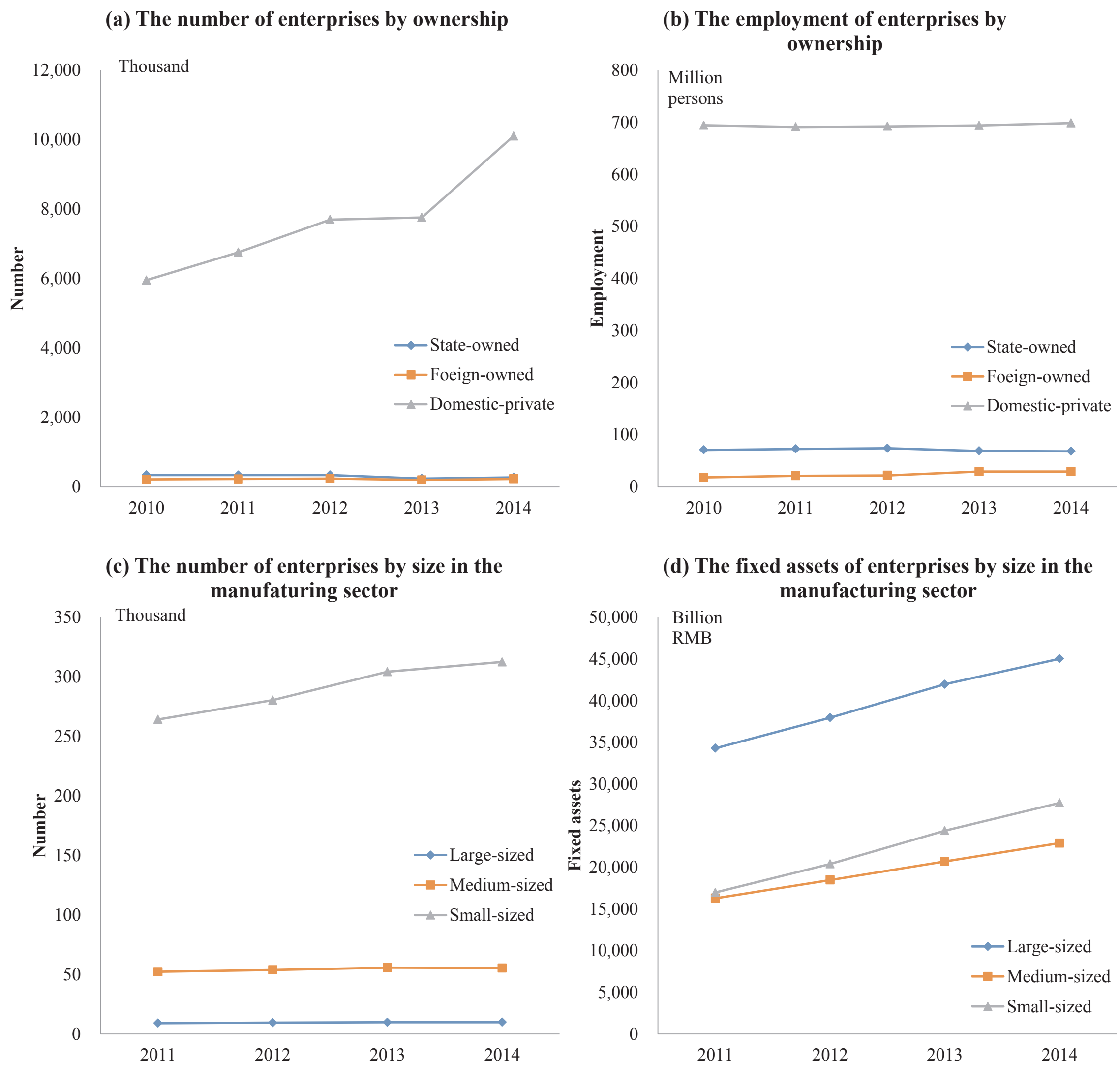


Fig. A1. Changes in number, employment, fixed assets of enterprises by firm size and ownership at the national level. Note: The coverage of firms in part (a) and (b) is based on the State Administration for Industry & Commerce (SAIC)'s official registration without considering the number of subsidiaries and branches. The firm size in part (c) and (d) is based on the China's National Statistics Bureau (NBS)'s definition only covering manufacturing enterprises with "designated size".

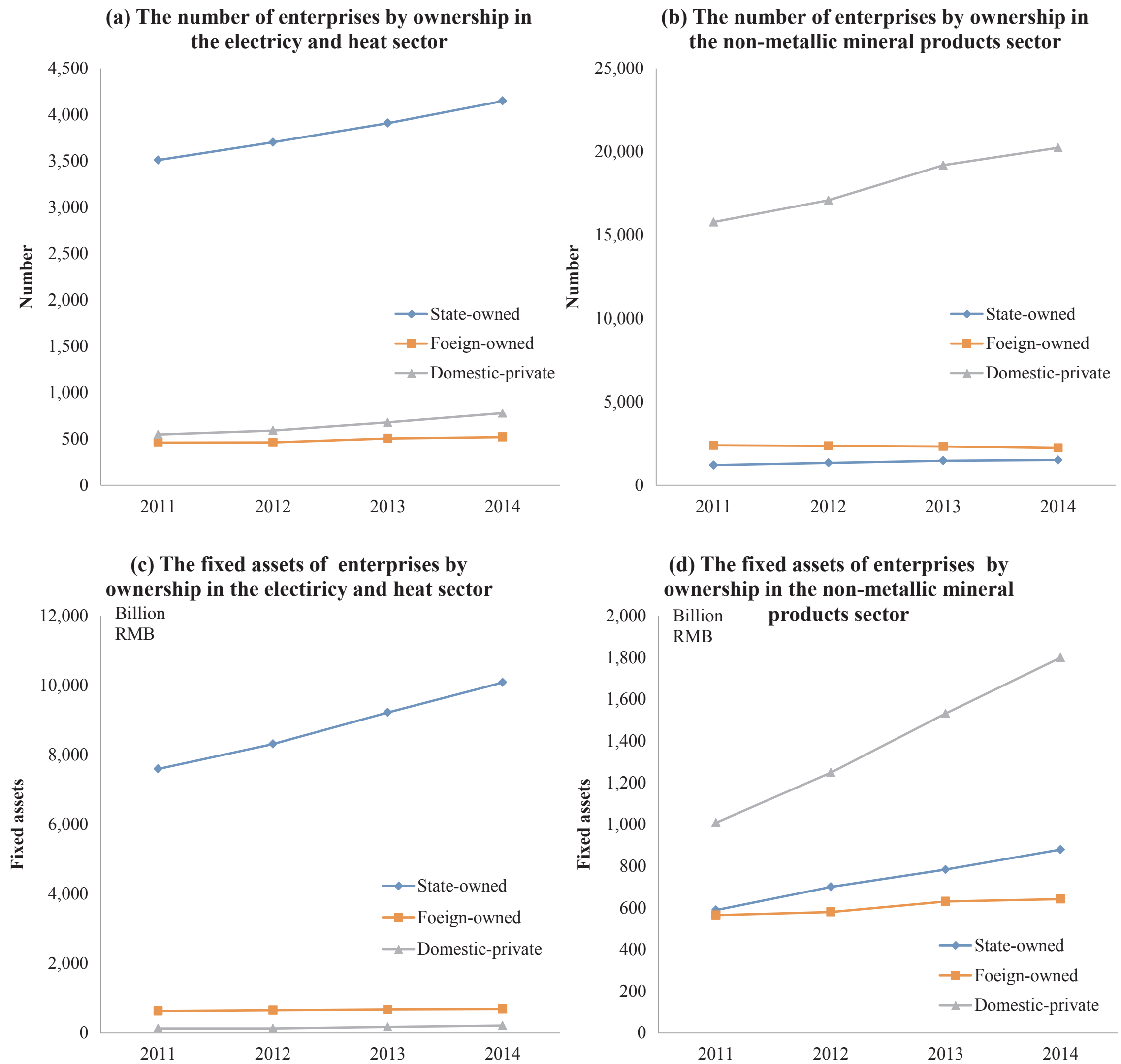
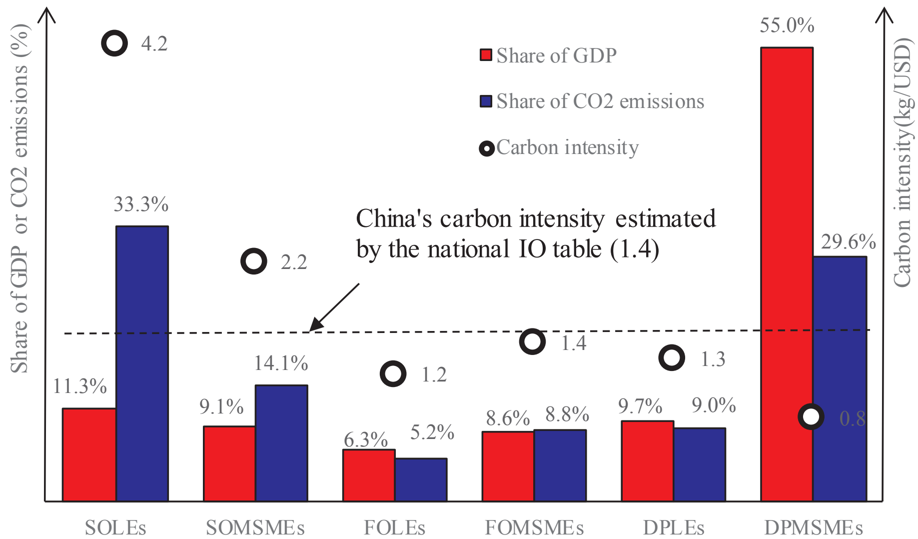


Fig. A2. Changes in number and fixed assets of enterprises by firm size and ownership at the sector level. Note: The ownership definition is based the State Administration for Industry & Commerce (SAIC)'s official registration. Firms only cover "enterprises with designated size" based on the China's National Statistics Bureau (NBS)'s definition.



	Large Enterprise (LEs)	Micro, Small and Medium-sized Enterprise (MSMEs)
State-owned (SO)	SOLEs: State-owned LEs	SOMSMEs: State-owned MSMEs
Foreign-owned (FO)	FOLEs: Foreign-owned LEs	FOMSMEs: Foreign-owned MSMEs
Domestic-private (DP)	DPLEs: Domestic-private LEs	DPMSMEs: Domestic-private MSMEs

Fig. A3. China's GDP, CO_2 emissions, and carbon intensity by firm size and ownership in 2010.

Table A1
. Sector classification and description.

42 Sectors	Sector Name	Sector Description
1	Agriculture	Farming; Forestry; Livestock; Fishery and Services in Support of Agriculture
2	Coal Mining	Mining and Washing of Coal
3	Crude Oil and Gas Mining	Extraction of Crude Oil and Natural Gas
4	Mining of Metal Ores	Mining of Ferrous and Non-Ferrous Metal Ores
5	Mining and Processing of Nonmetal Ores and Other Ores	Mining and Processing of Nonmetal Ores and Other Ores
6	Manufacture of Foods and Tobacco	Grinding of Grains; Processing of Forage; Refining of Vegetable Oil; Manufacture of Sugar; Slaughtering and Processing of Meat; Processing of Aquatic Product; Processing of Other Foods; Manufacture of Convenience Food; Manufacture of Liquid Milk and Dairy Products; Manufacture of Flavoring and Ferment Products; Manufacture of Alcohol and Wine; Processing of Soft Drinks and Purified Tea; Manufacture of Tobacco
7	Manufature of Textile	Spinning and Weaving, Printing and Dyeing of Cotton and Chemical Fiber; Spinning and Weaving, Dyeing and Finishing of Wool; Spinning and Weaving of Hemp and Tiffany; Manufacture of Textile products; Manufacture of Knitted Fabric and Its Product
8	Manufacture of Clothes and Shoes	Manufacture of Textile Wearing Apparel, Footwear, Caps; Manufacture of Leather, Fur, Feather (Down) and Its Products
9	Processing of Timbers and Manufacture of Furniture	Processing of Timbers; Manufacture of Wood, Bamboo, Rattan, Palm and Straw Products; Manufacture of Furniture
10	Manufacture of Paper and Articles for Culture, Education and Sports Activities	Manufacture of Paper and Paper Products; Printing and Reproduction of Recording Media; Manufacture of Articles for Culture, Education and Sports Activities
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	Processing of Petroleum and Nuclear Fuel; Coking
12	Chemical	Manufacture of Basic Chemical Raw Materials; Manufacture of Fertilizers; Manufacture of Pestcides; Manufacture of Paints, Printing Inks, Pigments and Similar Products; Manufacture of Synthetic Materials; Manufacture of Special Chemical Products; Manufacture of Daily-use Chemical Products; Manufacture of Medicines; Manufacture of Chemical Fiber; Manufacture of Rubber and Plastics
13	Non-metallic Mineral Products	Manufacture of Cement, Lime, Plaster; Manufacture of Brick, Stone and Other Building Materials; Manufacture of Glass and Its Products; Manufacture of Pottery and Porcelain; Manufacture of Fire-resistant Materials; Manufacture of Graphite and Other Nonmetallic Minerals Products
14	Metal smelting products	Iron-Smelting; Steel Making; Rolling of Stell; Smelting of Ferroalloy; Smelting of Non-Ferrous and Manufacture of Alloys; Rolling of Non-Ferrous Metals
15	Manufacture of Metal Products	Manufacture of Metal Products
16	Manufacture of General Purpose and Special Purpose Machinery	Manufacture of Boiler and Prime Mover; Manufacture of Metalworking Machine; Manufacture of Lifters; Manufacture of Pump, Valve and Similar Machinery; Manufacture of Other General Purpose Machinery; Manufacture of Special Purpose Machinery for Mining, Metallurgy and Construction; Manufacture of Special Purpose Machinery for Chemical Industry, Processing of Timber and Nonmetals; Manufacture of Special Purpose Machinery for Agriculture, Forsestry, Livestock and Fishery; Manufacture of Other Special Purpose Machinery

(continued on next page)

Table A1 (*continued*)

42 Sectors	Sector Name	Sector Description
17	Manufacture of Transport Equipment	Manufacture of Railroad Transport Equipment; Manufacture of Automobiles; Manufacture of Boats, Ships and Floating Devices; Manufacture of Other Transport Equipment
18	Manufacture of Electrical Machinery and Equipment	Manufacture of Generators; Manufacture of Equipment for Power Transmission and Distribution and Control; Manufacture of Wire, Cable, Optical Cable and Electrical Appliances; Manufacture of Household Electric and Non-Electric Appliances; Manufacture of Other Electrical Machinery and Equipment
19	Manufacture of Communication Equipment, Computer and Other Electronic Equipment	Manufacture of Communication Equipments; Manufacture of Radar and Broadcasting Equipment; Manufacture of Computer; Manufacture of Electronic Component; Manufacture of Household Audiovisual Apparatus; Manufacture of Other Electronic Equipment
20	Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work	Manufacture of Measuring Instruments; Manufacture of Machinery For Cultural Activity & Office Work
21	Manufacture of Artwork, Other Manufacture	Manufacture of Artwork, Other Manufacture
22	Scrap and Waste	Scrap and Waste
23	Electricity and Heat	Production and Supply of Electicity Power and Heat Power
24	Production and Distribution of Gas	Production and Distribution of Gas
25	Production and Distribution of Water	Production and Distribution of Water
26	Construction	Construction
27	Transportation and Warehousing	Transport Via Railway; Transport Via Road; Urban Public Traffic; Water Transport; Air Transport; Transport Via Pipeline; Loading, Unloading, Portage and Other Transport Services; Warehousing
28	Post Services	Post Services
29	Information Transmission, Computer Services and Software	Telecom & Other Information Transmission Services; Computer Services; Software Industry
30	Wholesale and Retail Trades	Wholesale and Retail Trades
31	Hotels and Catering Services	Hotels; Catering Services
32	Financial Intermediation	Banking, Security and Other Financial Activities; Insurance
33	Real Estate	Real Estate
34	Leasing and Business Services	Leasing; Business Services; Tourism
35	Research and Experimental Development	Research and Experimental Development
36	Comprehensive Technical services	Professional Technical Services; Services of Science and Technology Exchanges and Promotion; Geological Prospecting
37	Management of Water Conservancy, Environment and Public Facilities	Management of Water Conservancy; Environment Management; Management of Public Facilities
38	Services to Households and Other Services	Services to Household and Other Services
39	Education	Education
40	Health, Social Security and Social Welfare	Health; Social Security; Social Welfare
41	Culture, Sports and Entertainment	Jounalism and Publishing Activities; Broadcasting, Movie, Televisions and Autovisual Activities; Cultural and Art Activities; Sports Activities; Entertainment
42	Public Management and Social Organization	Public Management and Social Organization

Table A2
Layout of the augmented 2010 Chinese national IO table.

		Demand on intermediate products						Domestic Final Demand	Export	Total Output
		State-owned Enterprises		Foreign-owned Enterprises		Domestic private Enterprises				
		Large (SOLEs)	Micro, Small and Medium-sized (SOMSMEs)	Large (FOLEs)	Micro, Small and Medium-sized (FOMSMEs)	Large (DPLEs)	Micro, Small and Medium-sized (DPMSMEs)			
State-owned Enterprises	Large (SOLEs)	$Z^{SOLESOLE}$	$Z^{SOLESOMSME}$	$Z^{SOLEFOLE}$	$Z^{SOLEFOMSME}$	$Z^{SOLEDPLE}$	$Z^{SOLEDPMSME}$	F^{SOLE}	E^{SOLE}	X^{SOLE}
	Micro, Small and Medium-sized (SOMSMEs)	$Z^{SOMSMESOLE}$	$Z^{SOMSMESOMSME}$	$Z^{SOMSMEFOLE}$	$Z^{SOMSMEFOMSME}$	$Z^{SOMSMEDPLE}$	$Z^{SOMSMEDPMSME}$	F^{SOMSME}	E^{SOMSME}	X^{SOMSME}
Foreign-owned Enterprises	Large (FOLEs)	$Z^{FOLESOLE}$	$Z^{FOLESOMSME}$	$Z^{FOLEFOLE}$	$Z^{FOLEFOMSME}$	$Z^{FOLEDPLE}$	$Z^{FOLEDPMSME}$	F^{FOLE}	E^{FOLE}	X^{FOLE}
	Micro, Small and Medium-sized (FIMSMEs)	$Z^{FIMSMESOLE}$	$Z^{FIMSMESOMSME}$	$Z^{FIMSMEFOLE}$	$Z^{FIMSMEFOMSME}$	$Z^{FIMSMDPLE}$	$Z^{FIMSMEDPMSME}$	F^{FIMSME}	E^{FIMSME}	X^{FIMSME}
Domestic private Enterprises	Large (DPLEs)	$Z^{DPLESOLE}$	$Z^{DPLESOMSME}$	$Z^{DPLEFOLE}$	$Z^{DPLEFOMSME}$	$Z^{DPLEDPLE}$	$Z^{DPLEDPMSME}$	F^{DPLE}	E^{DPLE}	X^{DPLE}
	Micro, Small and Medium-sized (DPMSMEs)	$Z^{DPMSMESOLE}$	$Z^{DPSMESOMSME}$	$Z^{DPMSMEFOLE}$	$Z^{DPSMEFOMSME}$	$Z^{DPMSMEDPLE}$	$Z^{DPMSMEDPMSME}$	F^{DPMSME}	E^{DPMSME}	X^{DPMSME}
Import		Z^{MSOLE}	$Z^{MSOMSME}$	Z^{MFOLE}	$Z^{MFOMSME}$	Z^{MDPLE}	$Z^{MDPMSME}$	F^{M}	0	0
Value-added		V^{SOLE}	V^{SOMSME}	V^{FOLE}	V^{FOMSME}	V^{DPLE}	V^{DPMSME}			
Total Input		$(X^{SOLE})^{t}$	$(X^{SOMSME})^{t}$	$(X^{FOLE})^{t}$	$(X^{FOMSME})^{t}$	$(X^{DPLE})^{t}$	$(X^{DPMSME})^{t}$			

	Large Enterprise (LEs)	Micro, Small and Medium-sized Enterprise (MSMEs)
State-owned (SO)	SOLEs: State-owned LEs	SOMSMEs: State-owned MSMEs
Foreign-owned (FO)	FOLEs: Foreign-owned LEs	FOMSMEs: Foreign-owned MSMEs
Domestic-private (DP)	DPLEs: Domestic-private LEs	DPMSMEs: Domestic-private MSMEs

Note: M for imports, Z for intermediate input matrices, F for domestic final demands, E for exports, X for gross output, and V for value added.

Table A3
China's economic structure change.

Year	(a) Components in total output					
	Share of intermediate inputs in total output	Share of final consumption in total output	Share of capital formation in total output	Share of export in total output	Share of import in total output	Sum
2000	63.2%	23.1%	12.9%	8.1%	−7.7%	100.0%
2004	64.5%	19.3%	15.4%	11.6%	−11.2%	100.0%
2008	67.0%	16.0%	14.5%	11.3%	−9.0%	100.0%
2010	67.1%	15.7%	15.8%	9.4%	−8.4%	100.0%
2014	67.6%	15.9%	15.1%	7.6%	−6.7%	100.0%
	(b) Absolute change of each component between two years					
Between two years	Share of intermediate inputs in total output	Share of final consumption in total output	Share of capital formation in total output	Share of export in total output	Share of import in total output	Standard deviation
2000–2004	1.3%	−3.8%	2.4%	3.6%	−3.5%	0.031
2004–2008	2.5%	−3.4%	−0.8%	−0.4%	2.2%	0.021
2010–2014	0.5%	0.2%	−0.7%	−1.8%	1.7%	0.012
	(c) Standard deviation of 2-year industrial structure change					
Between two years	Industrial output	Inter-industrial interaction	Final demands			
2000–2004	0.0050	0.0006	0.0036			
2004–2008	0.0040	0.0004	0.0102			
2010–2014	0.0017	0.0002	0.0017			

Note: Part (a) shows the share of each component in total output for the five target years. Part (b) shows the absolute change of each component between 2000 and 2004, 2004 and 2008, 2010 and 2014 respectively. The period between 2000 and 2004 represents the timing before and after China's accession to the WTO in 2001; the period between 2004 and 2008 represents the timing before the 2008 financial crisis; the period between 2010 and 2014 represents the timing after the 2008 financial crisis and also between the target year used in the paper and the most recent reference year of the available data. The most recent available data that can represent the Chinese economic structure in detail is from the Chinese Supply-Use Tables provided by the 2016 version of the World Input-Output Database, which covers 65 sectors from 2000 to 2014. From the standard deviation shown in part (b), it's easy to see that there was not significant change in China's economic structure happened between 2010 and 2014, compared to those between 2000 and 2004, and between 2004 and 2008. In Part (c), the industrial output structure is measured by the share of each industrial output in the national total output; the inter-industrial interaction structure is measured by the share of each transaction of intermediate goods and services in the national total production of intermediates; the final demand structure is measured by the share of each final demand item by industry in the national total final demands. The standard deviation of industrial structure change for the three target periods shows that changes happened between 2010 and 2014 is the smallest one.

Table A4
Changes in China's energy use structure between 2010 and 2015.

	(a) Components of energy use at national level				
	Coal	Crude Oil & Natural Gas	Petroleum & Coke	Gas Supply	Sum
2010	61.4%	4.3%	30.9%	3.4%	100.0%
2015	58.5%	5.7%	30.1%	5.7%	100.0%
	(b) Components of energy use in the electricity and steam sector				
2010	94.1%	2.1%	1.3%	2.5%	100.0%
2015	92.7%	3.2%	0.9%	3.2%	100.0%
	(c) Components of energy use in the metal smelting products sector				
2010	20.2%	0.8%	69.9%	9.1%	100.0%
2015	20.2%	1.1%	61.7%	17.0%	100.0%
	(d) Components of energy use in the non-metallic mineral products sector				
2010	85.7%	2.4%	10.6%	1.3%	100.0%
2015	84.5%	2.9%	9.9%	2.6%	100.0%
	(e) Components of energy use in the chemical sector				
2010	60.8%	9.3%	25.7%	4.1%	100.0%
2015	66.4%	10.7%	16.5%	6.4%	100.0%
	(f) Components of energy use in the transportation and warehousing sector				
2010	1.9%	4.6%	92.5%	1.0%	100.0%
2015	1.0%	7.4%	90.1%	1.4%	100.0%

Note: Energy use data (unit: tce) is from Chinese Energy Statistics Yearbook. It's clear, there was not significant structure change happed in energy use at both national and sector levels between 2010 and 2015 (excluding the change of petroleum and coke use in the chemical sector, gas supply in both the metal smelting and chemical sectors, but these sectors are not the main research target for our policy discussion in the paper).

Table A5
CO_2 emissions, GDP and carbon intensity across firms with different ownership at the sector level.

Sector	CO_2 emissions ($MtCO_2$)	Share by ownership		
		SOEs	FOEs	DPEs
Electricity and heat	3,699 (44%)	83.3%	5.4%	11.2%
Non-metallic mineral products	1,508 (18%)	6.1%	16.3%	77.6%
Chemical	786 (9%)	13.8%	32.9%	53.3%
Metal smelting products	760 (9%)	25.8%	21.4%	52.8%
Transportation and warehousing	574 (7%)	38.1%	8.7%	53.2%
All other sectors	1,091 (13%)	26.8%	23.7%	49.5%
National total	8,418 (100%)	47.4%	14.0%	38.6%
Sector	GDP (million USD)	Share by ownership		
		SOEs	FOEs	DPEs
Electricity and heat	162 (3%)	77.0%	7.7%	15.4%
Non-metallic mineral products	130 (2%)	5.0%	18.2%	76.8%
Chemical	267 (4%)	9.6%	32.8%	57.5%
Metal smelting products	216 (4%)	31.1%	16.1%	52.9%
Transportation and warehousing	287 (5%)	45.6%	4.8%	49.6%
All other sectors	4,901 (82%)	17.6%	14.6%	67.8%
National total	5,963 (100%)	20.4%	14.9%	64.7%
Sector	Carbon intensity ($kgCO_2$/USD)	Intensity by ownership		
		SOEs	FOEs	DPEs
Electricity and heat	22.8	24.7	16.3	16.7
Non-metallic mineral products	11.6	14.2	10.4	11.7
Chemical	2.9	4.2	3.0	2.7
Metal smelting products	3.5	2.9	4.7	3.5
Transportation and warehousing	2.0	1.7	3.6	2.1
All other sectors	0.2	0.3	0.4	0.2
National average	1.4	3.3	1.3	0.8

Note: SOEs are State-owned Enterprises; FOEs are Foreign-owned Enterprises; DPEs are Domestic Private Enterprises.

Table A6
The definition of firm size based on NBS's 2011 version.

Industry	Indicator	Unit	Large	Medium	Small
Manufacture	Employment	Persons	> =1000	300–1000	< 300
	Total Sales	RMB10000	> =40000	2000–40000	< 2000
	Total Assets	RMB10000	> =40000	4000–40000	< 4000
Construction	Total Sales	RMB10000	> =80000	6000–80000	< 6000
	Total Assets	RMB10000	> =80000	5000–80000	< 5000
Wholesales	Employment	Persons	> =200	20–200	< 20
	Total Sales	RMB10000	> =40000	5000–40000	< 5000
Retails	Employment	Persons	> =300	50–300	< 50
	Total Sales	RMB10000	> =20000	500–20000	< 500
Transportion	Employment	Persons	> =1000	300–1000	< 300
	Total Sales	RMB10000	> =30000	3000–30000	< 3000
Postal Services	Employment	Persons	> =1000	300–1000	< 300
	Total Sales	RMB10000	> =30000	2000–30000	< 2000
Accommodation & Catering	Employment	Persons	> =300	100–300	< 100
	Total Sales	RMB10000	> =10000	2000–10000	< 2000
Finance and Banking	Employment	Persons	> =200	< 200	
	Total Sales	RMB10000	> =30000	< 30000	
Real Estates	Employment	Persons	> =200	< 200	
	Total Sales	RMB10000	> =30000	< 30000	
Other Service Industries	Employment	Persons	> =500	< 500	

1. Manufacture above also includes Mining and Electricity, Gas, and Utility Production and Supply sectors.
2. The large and medium sized firms should meet criteria for both sales and number of employment.

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